RELEVANCE OF AFIS HVI AND MICROMAT TO WHITE SPECKS

Patricia Bel
USDA, ARS, SRRC
New Orleans, LA
Bugao Xu
University of Texas at Austin
Austin, TX

Abstract

White speck neps cause significant financial losses to the textile industry. The mills need a high speed method to predict this defect so that the fibers with high white speck potential can be put into the proper product line, such as white sheeting, toweling, etc., thereby maximizing the fiber's potential and minimizing white specks in dyed fabrics. Initial studies indicate that different prediction equations will be needed for each level of lint cleaning. The cottons for the US Cotton Variety Textile Processing Trials were grown in Georgia, Mississippi, and Texas during the 2001 season. The Georgia cottons were grown in the same field, spindle picked and ginned with one lint cleaner. The Texas cottons were grown in one field, stripper picked and ginned using two lint cleaners. The Mississippi cottons were grown in the same area and obtained commercially without ginning information. HVI, AFIS, and Micromat F/MT were used to measure fiber properties from the bale. These data are analyzed and related to white specks from these three studies. Ultimately we would like to develop strong predictions of white specks from high-speed instruments that test bale fibers, and include the white speck potential in the classification of cottons.

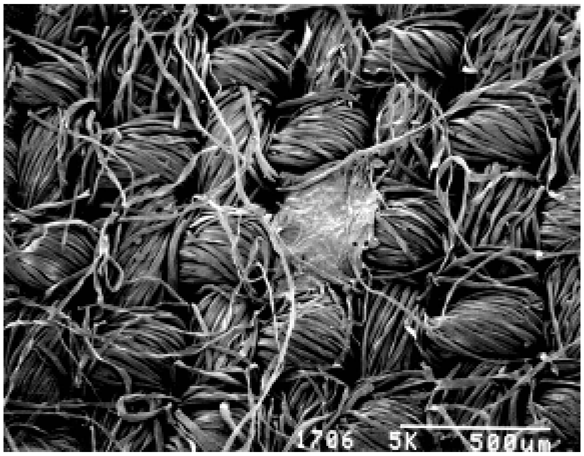
Introduction

White speck neps appear are defined as small undyeable, undeveloped or immature fiber clusters that appear white on the surface of a darkly dyed fabric (Figure 1). We can use image analysis to quantify the problem (Figure 2). Unfortunately, these defects are not recognized until after the dyeing stage of processing, resulting in poor quality fabric and large losses to the mill. Often a whole region, sometimes as large as a state or even an entire nation, is avoided by buyers to avoid the problem in the future.

Figure 1: White Speck Fabric Scan

Figure 2: Scan Analyzed by Dr. Xu's AutoRate Program

Neps originate from growth, harvesting, ginning, and processing (Wegener, 1980). The growth neps consist of mostly dead or immature fiber and are the ultimate cause of white specks (see Figure 3 and Figure 4).



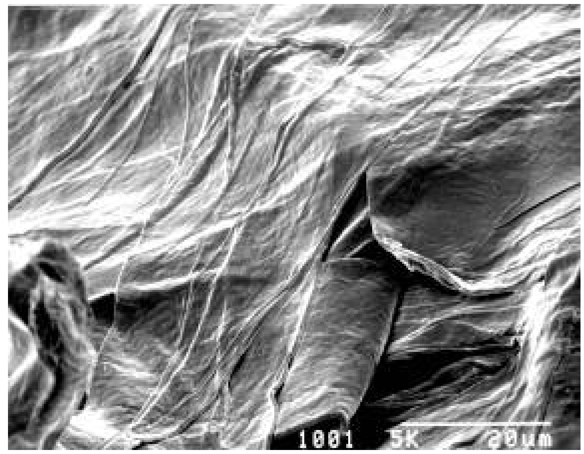


Figure 3: White Speck on Dyed Fabric (low magnification). Figure 4: High Magnification of White Speck

Immature fibers, due to their lack of longitudinal rigidity, are particularly vulnerable to becoming mechanical neps (entangled fibers formed by the mechanical actions of processing as in harvesting, ginning, opening, cleaning and carding) as seen in Figure 5. Neps are often formed from fiber breakage, which causes the fiber to coil upon itself (Wegener, 1980). Lint cleaning, carding and drawing produce neps through a stress buildup/sudden release mechanism, which induces buckling along the fiber length. Long, fine fibers have a low longitudinal rigidity, and are more likely to entangle with other fibers and with themselves to form mechanical neps. As the cotton fiber develops, it first elongates and then its cell wall thickens. The relative thickness of the wall is characterized as the fiber's maturity. Coarse fibers or fibers with thick secondary walls ($\theta > 0.5$, see Figure 6) are less prone to forming mechanical neps during processing (Alon & Alexander, 1978). In contrast, immature fibers have very little cellulose in the cell wall resulting in a small θ and are therefore very fine and flat as seen in Figure 4. Often other fibers are involved in the recoiling, producing entanglements. These entanglements have a high level of immature fibers, which lack the resilience to disentangle themselves (Bargeron, 1993). In order to obtain a good paralellization of fibers for spinning, the fibers are carded. Fibers will stretch and suddenly release in-between the carding cylinders and form new entanglements. Immature, fine-fiber cottons tend to form neps more readily than do mature fibers, so any field condition or harvesting method that increases the level of immature fibers will increase white speck neps in yarns and fabrics.

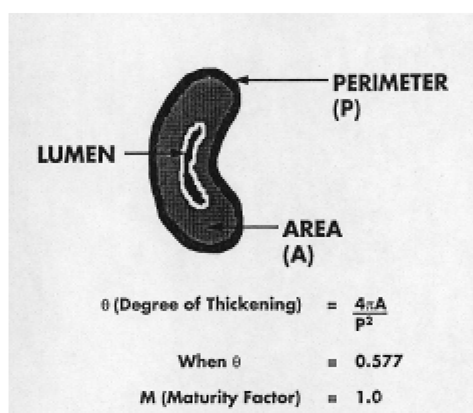


Figure 5: White Speck Nep (Mature and Immature fibers entangled) **Figure 6:** Fiber Cross-Section

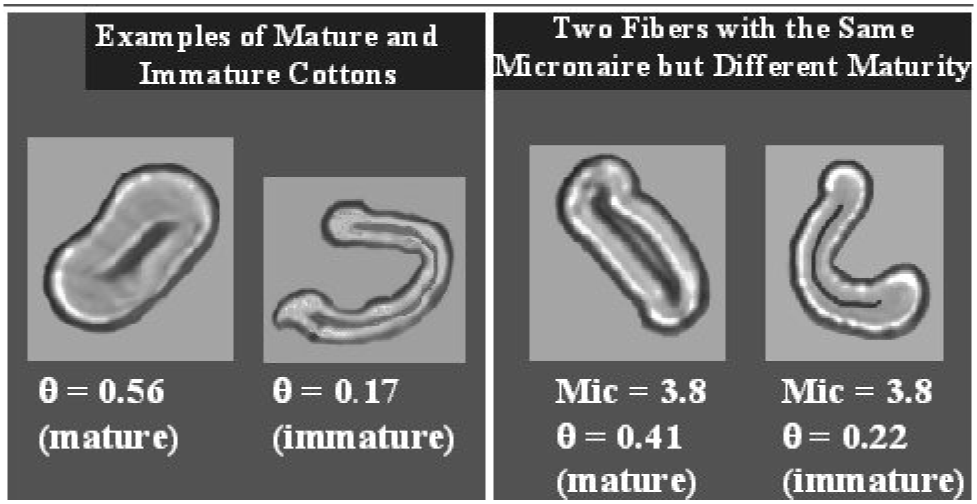


Figure 7: Mature and immature fibers. The first set shows a very mature and a very immature fiber. The second set shows a mature and an immature fiber with the same micronaire.

Theta is a measure of circularity (0 to 1 range); the nearer theta is to 1, the closer the fiber cross-section is to a perfect circle. Notice that in both sets of pictures (Figure 7) the mature fiber has a much more rounded cross-section, whereas the immature fibers collapse on themselves and have more of a “C” shape. The more secondary wall in a fiber, the more cellulose is present and the fiber is rounder. When a fiber is dyed, the dye is absorbed into the cellouse. An immature fiber will be difficult to dye since there is a limited amount of cellulose present and it will ultimately appear as a white speck on the dyed fabric. There has been some discussion that micronaire by itself is not a reliable indicator of maturity which can be seen in the second set of pictures in Figure 7. Individuals who work closely with cotton fiber maturity studies have indicated that micronaire is a good indicator of maturity per variety, but not necessarily across varieties. A typical variety may be fully mature with a micronaire of 3.8 and another may not be fully mature until it reaches a micronaire of 4.1. The variability in the circularity of the fibers may be a better way to evaluate a sample’s maturity since individual fibers are evaluated as opposed to an average value such as the plug of fibers measured for micronaire. Theta CV% has been shown to be a good indicator of maturity and hence white specks in past studies (Bel-Berger, 1999).

Materials and Methods

Each bale for each variety was sampled and blended for processing. Yarns were made by CQRS from one blended bale per variety per location (21 Blocks). The 21 yarns were woven in a common combed warp producing a filling faced Sateen fabric at SRRC. The fabrics were dyed and image analyzed at SRRC using Dr. Bugao Xu’s AutoRate Program (April 2002 version).

Two varieties of Fibermax, FM 832 AND FM 966, were grown in Georgia, Mississippi, and Texas during the 2000 season as part of a study on the utility of different fiber property measurements in determining suitability for spinning. The emphasis of this part of study was on how the average values of fiber fineness and maturity as well as distributions varied with growing location.

Blending: Eight bales of cotton were blended for each variety and location

Opening & Carding: 2 - 300 pound blended bales were carded at 150 pounds per hour into 70 gr. card sliver.

Table 1: Varieties and locations in which they were grown

Block	Variety	Location
1	Fibermax 832	Texas
2	Paymaster 2800	Texas
3	Paymaster 2200	Texas
4	Fibermax 819	Texas
5	Fibermax 989	Texas
6	Fibermax 958	Texas
7	Fibermax 966	Texas
8	Paymaster 2326	Texas
9	Delta & Pine Land 491	Georgia
10	Phytogen 355	Georgia
11	Fibermax 966	Georgia
12	Delta Pearl	Georgia
13	Fibermax 832	Georgia
14	Sure Grow 747	Georgia
15	Delta Pearl	Mississippi
16	PSC 355	Mississippi
17	Fibermax 832	Mississippi
18	Delta & Pine Land 491	Mississippi
19	Fibermax 966	Mississippi
20	Sure Grow 747	Mississippi
21	Phytogen 1218 B/R	Mississippi

Drawing 1st: The card sliver was split into 4 equal groups for further processing:

1. **For Open End Spinning** - Used RSB 51 - Made 55 gr. sliver for spinning.
2. **For Ring Spinning** - Used RSB 951 - Made 60 gr. sliver for 2nd drawing.
3. **For Vortex Spinning** - Used RSB 951 - Made 55 gr. sliver for 2nd drawing.

Drawing 2nd:
1. **For Ring Spinning** - Used RSB51 -Made 61 gr. sliver for roving.
2. **For Vortex Spinning** - Used RSB 951 -Made 45 gr. sliver for 3rd drawing.

Drawing 3rd:
1. **For Vortex Spinning** - Used RSB 51 -Made 24 cans for spinning 40 gr. sliver.

Roving For Ring Spinning: Made 0.75 HR (Hank Roving) with a 1.30 TM (Twist Multiplier) for spinning.

Spinning:

1. **OES:** Spin 20/1's with a 4.6 TM.
2. **Ring:** Spin 20/1's with a 4.3 TM.
3. **Vortex:** Spin 20/1's.

Weaving: The yarns were woven at 90 picks per inch as a 4/1 filling faced sateen (a 5 harness sateen with a 2 move sateen pattern) in a combed common warp (30/1 ring yarns, 72 ends/inch).

Dyeing of Fabric: The fabric was finished with a 0.1% Prechem 70, 0.3% T.S.P.P. boiloff, a caustic scour of 1.1% Prechem SN, 1.1% Mayquest 80, 0.1% Prechem 70 and 0.7% sodium hydroxide (caustic soda), followed by the same boiloff procedure. It was then bleached (0.1% Prechem 70, 0.5% Mayquest BLE and 3.0% Peroxide (Albone 35) followed by an acid sour (0.1% acetic acid) and dyed with 4% Cibacron Navy FG Blue (owf), 0.5% Calgon, 8% NaCl, 0.8% Na_2CO_3 (soda ash) and 0.5% Triton X-100. This dye has a high propensity for highlighting white specks in finished fabrics.

Image Analysis: Image analysis was used to quantify white speck defects. Using a HP Scan Jet 6300C flatbed scanner, an image was converted into pixels, measured and analyzed by Dr. Xu's Autorate computer program (Version AR-04-03 (April 2003). The region of interest (ROI) was set at 5 inches by 5 inches with 4 adjacent images analyzed for a total viewing area of 100 square inches. The images were accessed in the Autorate program and the brightness adjusted to 120. The size and the number of specks were evaluated (see Figures 1 and 2) and the ratio of the white speck area to the sampling area, or the % White, was calculated. To ensure that white specks were being detected properly, the minimum pixel size was set at 3 pixels and the contrast was set at 22 using several samples and remained the same for the duration of the testing (the contrast can be adjusted at any time, but for these samples the operator found that a contrast of 22 was good for all of the fabrics). The contrast dictates what is detected as white and thus contributes to the percent white of the sampled area.

Fiber Samples for testing :

4 - Classers Memphis
1 - Classer SRRC
2 - 1 lb. Raw stock each bale (1- Testing Lab, 1- Reference)
1 - 5 lb. Raw stock each bale
1 - ½ lb. From each bale for S.A.
2 - 1 lb. from blended bale, GBRA, After RN, and FBK (1- Clemson, 1- SRRC)
1 - ½ lb. From blended stock for S.A. from each lot
1 - 5 lb. Blended stock from each lot
1 - 3 lb. Blended stock from blended bale
1 - 2 lb. Blended stock from Variety & location Card sliver – Evenness (save for Clemson & ¼ lbs - SRRC AFIS)
1 - 2 lb. Finish Drawing sliver - Evenness (save for Clemson & ¼ lbs - SRRC AFIS)

Instrumentation used to measure average micronaire, fineness and maturity included the HVI, AFIS (Version 2, 4 & 5), and Micromat F/MT. Image analysis of microscopic fiber cross-sections was utilized to determine the distributions of fiber wall area, perimeter, and degree of thickening (θ). Ranges of some of the average fiber properties measured in the study included: $2.9 < \text{Micronaire} < 4.5$; $48\ \mu m < \text{perimeter} < 55\ \mu m$; $90\ \mu m^2 < \text{wall area} < 140\ \mu m^2$; and $0.45 < \theta < 0.60$.

Results

Our goal is to use high-speed tests to predict fabric quality from the fiber information. Research on cotton from bale through fabric has shown that gin processing data and fiber properties are both necessary to predict white speck on finished fabrics[5], but this information usually is not available to the mills when they purchase their bales of cotton. The level of lint cleaning in the gin can change the meaning of the fiber data when related to yarn and fabric properties, and it is even more obvious if the card wire is worn (Bel-Berger, 1996). Because of this, it is not surprising that several mills have their cotton custom ginned so they have some history of the cotton's previous processing. In this study, we had the cottons ginned at one gin for each location so that the differences between gins could be minimized, at least by location.

Immature fibers are the ultimate cause of white specks and micronaire is the measurement that has been classically used to judge maturity. In Figure 8, we can see that micronaire as measured by HVI and FMT predicts approximately 75% of the white specks seen on the dyed Fabric. Micronafis is the Micronaire measurement provided by AFIS, but it falls short (only 53%) of the classical measurements.

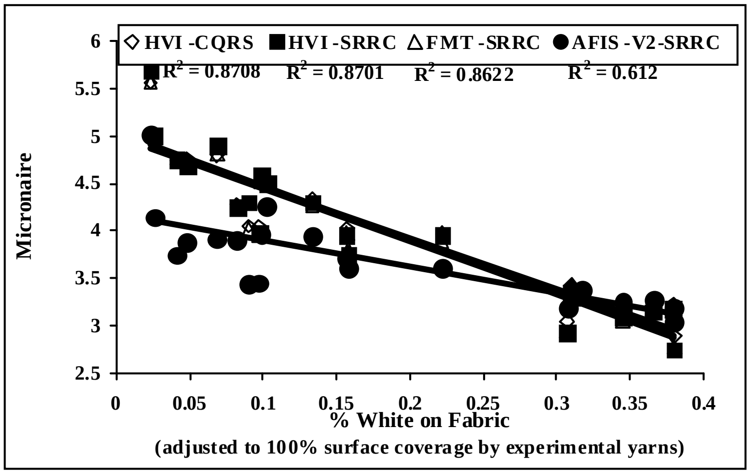


Figure 8 :Micronaire/Micronafis (as measured by HVI (both at CQRS and SRRC) , FMT and AFIS Version 2) vs %White on Dyed Fabric

Mechanical entanglements develop when cotton is exposed to processing (harvesting, ginning and milling). As Alon and Alexander (Alon & Alexander, 1978) pointed out, the fiber tangles on itself during processing and the longer and more immature the fiber is, the more it is prone to nepping. The fiber is stretched and whips back on itself, entangling other fibers in the process. In Figure 9, the Buckling Coefficient (from HVI data as defined below) is graphed against white speck. In this case, we see little change as compared to the regressions in Figure 8.

Buckling Coefficient = L^2/μ^2

μ = Micronaire Value

L = 2.5% Span Length

Next we studied maturity data as measured by FMT. The best relationship is calculated using FMT micronaire and cell wall thickness (Figure 10), but it does little to improve the overall prediction of white specks in the fabrics.

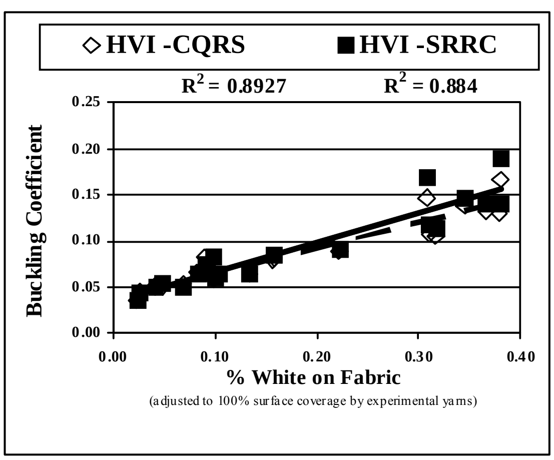


Figure 9: HVI Buckling Coefficient

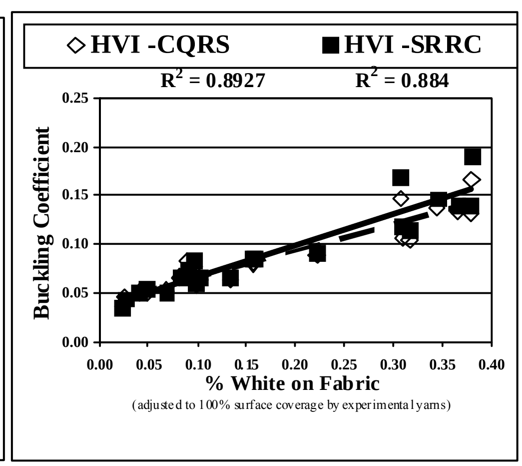


Figure 10: % White Predicted by FMT, based on Mic, Cell Wall Thickness and Perimeter

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during this study and they had a variety of fiber maturity m
Figure 4 shows the best predictions of white specks from the fib... properties for each version.

Table 2. Fiber maturity measurements that related to white specks

AFIS V2 (SRRC)	AFIS V4 (SRRC)	Version5 (CQRS)
R^2 = 0.96 Adjusted R^2 = 0.92	R^2 = 0.94 Adjusted R^2 = 0.92	R^2 = 0.94 Adjusted R^2 = 0.92
AFIS Maturity Measurements Used to develop best predictions of White specks for each Version of AFIS		
L(w) Length by weight MICRONAFIS THETA CV% IFC (Immature Fiber Content) Cell Wall Thickness A(n) (Area of Fiber Cross-section) A(n)CV% D(n) (Diameter of FiberCross-section) FFF (Fine Fiber Fraction)	Nep IFF (Immature Fiber Fraction) Maturity Ratio Fineness UQL(w) Upper Quartile Length	UQL(w) Upper Quartile Length Nep Count/g Fineness Nep Size

Note: Only Version 2 has Theta CV%, which was discussed earlier as a good physical measurement of maturity.

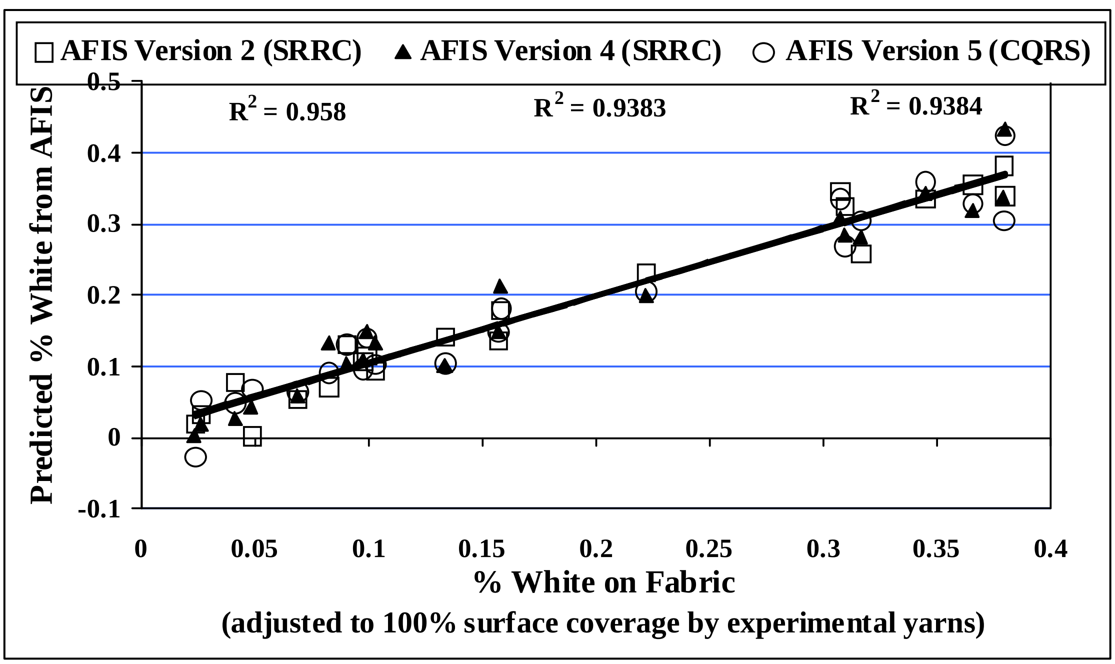

Figure 11: AFIS predictions of white specks on fabric from fiber data.

From the regressions in Figure 11, it is clear that AFIS does provide the best prediction of White Specks from the systems studied. Both the R square and adjusted R square are reported and even though each version of AFIS uses different fiber measurements in the prediction, it can be seen that the adjusted R square is in the same range (Adjusted R^2 = 0.92). For all three systems, length and maturity are the most important indicators of white specks as expected from the buckling coefficient theory. Version 2 predicts as much as 96% of the white specks. Version 2 was developed in conjunction with SRRC scientist using fiber samples that had matching cross-section data and has the highest R square.

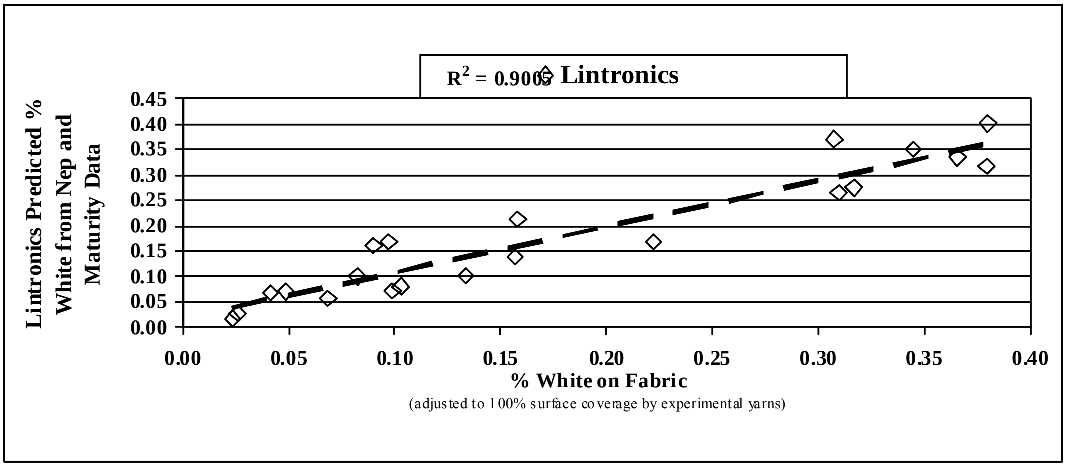

Figure 12: Lintronics predictions of white specks on fabric from fiber data.

Lintronics measures fiber maturity in a similar manner to the FMT, but it also makes a web similar to card web and then image analyzes it for neps and seed coat fragments. The combination of Nep measurements and maturity measurements result in a good prediction of white specks on dyed fabrics. The prediction is based on the regression of Nep count/gram, Seed Coat Neps/gram, Micronaire, Fineness, Maturity, and Length resulting in an R-Square of 0.9 and an adjusted R-Square of 0.86.

Conclusions

This study shows promise for predicting white specks from bale fiber data using systems currently on the market. The best relationships between fiber data and the corresponding white specks included some measurement of maturity for all of the high-speed systems. The systems with length measurements have length as a factor, as expected from the buckling coefficient theory of Alon and Alexander. All of the systems use maturity measurements and the best predictions come from Lintronics and AFIS, which actually generate neps in the bale fiber and then measure the level of neps. The AFIS data (all three Versions) show the strongest correlation with white speck neps. This study has extreme levels of white specks and should be a good base for developing predictions. This study is the beginning of a large database under development, which is needed to develop these relationships further, but once developed, they will be an invaluable tool to the mills. We will be obtaining all of these fiber measurements and processing the cotton identically through to dyed fabrics. This database should ultimately result in the "White Speck Potential" of cotton bales and could eventually be incorporated into the marketing system.

This study showed a distinctly higher level of white specks for fabrics woven from ring spun yarns as compared to vortex or rotor (open-end) spun yarns. Both vortex and rotor spinning systems have an opening feature that aligns the fibers and removes trash; obviously, it is also removing white specks. Once a White Speck Potential (WSP) value can be developed from this type of research it can be used as a tool by the mills and breeders. Bales with high WSP can be put into a special class for white fabrics only, or used for combed, vortex or rotor spun yarns, thus maximizing the fiber's potential and minimizing mill losses due to white specks. Breeders will be able to change the future of US cottons, by eliminating varieties with high WSP early on in the breeding process, without going to full field studies.

Acknowledgments

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CQRS Staff and SRRC (Cotton Fiber Quality and Textile Engineering) Staffs for all of their efforts in spinning, weaving, dyeing and analyzing the fibers, yarns and fabrics.

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